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# RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Department of the Navy

INCIPIENT SPIN CHARACTERISTICS OF A 1/25-SCALE MODEL

OF THE CHANCE VUGHT XF8U-1 AIRPLANE

TED NO. NACA AD 3118

By Frederick M. Healy

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Langley Field, Va.

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RESEARCH MEMORANDUM

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# INCIPIENT SPIN CHARACTERISTICS OF A 1/25-SCALE MODEL OF THE CHANCE VUGHT XF8U-1 AIRPLANE

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## SUMMARY

Incipient spin characteristics have been investigated on a 1/25-scale dynamic model of the Chance Vought XF8U-1 airplane. The model was launched by a catapult apparatus into free flight at the angle of attack and air-speed corresponding to the stall with various control settings, and the motions obtained were photographed. The model was loaded as lightly as possible because of the limitations of the catapult apparatus. Leading-edge droop, landing gear, speed brakes, and engine effects were not simulated.

The results indicated that the model would pitch up and diverge directionally when launched with the horizontal tail set between one-half and full up. With the horizontal tail one-half up, available space limited the divergence to less than one turn when rudder and ailerons were undeflected, but deflecting the rudder and ailerons allowed typical spin motions to develop. With the horizontal tail set full up, only moderate divergence was observed even with rudder and ailerons deflected, indicating that full-up horizontal tail delayed spin entry somewhat. The ailerons were very influential in initiating spin entry, and the model spin rotation was always in the opposite direction to the aileron setting (that is, the model entered a spin to the right with the stick deflected laterally to the left). The pilot, therefore, should avoid as far as possible the use of ailerons in low-speed flight. Post-stall yawing divergences could be greatly reduced by increasing the vertical-fin area or by use of suitably placed canard surfaces.

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## INTRODUCTION

At the request of the Bureau of Aeronautics, Department of the Navy, an investigation has been made of the incipient spin characteristics of a 1/25-scale model of the Chance Vought XF8U-1 airplane on a catapult apparatus at the Langley Laboratory. The XF8U-1 is a jet-propelled, single-seat fighter airplane with a swept wing mounted high on the fuselage and an all-movable horizontal tail. Results for developed spins of the XF8U-1 model in the Langley free-spinning tunnel are presented in reference 1.

The model was launched at the angle of attack and airspeed corresponding to the stall, with various combinations of control deflections. The track of the catapult was set to the steepest available glide-path angle below the horizontal ( $14.5^\circ$ ) to decrease the possibility of the model's striking the wall above the safety net in the event of an extreme pitch-up. Motion pictures were made of the flights. Improvement of the directional characteristics of the model at and beyond the stall by increasing the vertical-fin area and by using canard surfaces near the nose was investigated. Leading-edge droop, landing gear, and speed brakes were not simulated on the model. No provision was made on the model to simulate engine thrust or gyroscopic effects, or to deflect the control surfaces during flight.

## SYMBOLS

b	wing span, ft
$\bar{c}$	mean aerodynamic chord, ft
S	wing area, sq ft
x	distance from leading edge of mean aerodynamic chord rearward to center of gravity
z	distance between center of gravity and fuselage reference line (positive when center of gravity is below line)
m	mass of airplane, slugs
$I_X, I_Y, I_Z$	moments of inertia about X, Y, and Z body axes, respectively, slug-ft <sup>2</sup>
$\frac{I_X - I_Y}{mb^2}$	inertia yawing-moment parameter

$\frac{I_Y - I_Z}{mb^2}$	inertia rolling-moment parameter
$\frac{I_Z - I_X}{mb^2}$	inertia pitching-moment parameter
$\rho$	air density, slugs/cu ft
$\mu$	relative density of airplane, $\frac{m}{\rho S b}$
F.S.	fuselage station

#### APPARATUS AND METHODS

##### Model

The 1/25-scale model of the Chance Vought XF8U-1 airplane was furnished by the Bureau of Aeronautics, Department of the Navy. A three-view drawing of the model as tested is shown in figure 1. A photograph of the model is shown in figure 2. The dimensional characteristics of the airplane are presented in table I.

##### Testing Technique

The technique employed for the tests was generally similar to that described in reference 2. The launching apparatus was located inside a building, approximately 55 feet above the floor. The catapult consisted essentially of a carriage that was propelled along a track by a shock cord and accelerated the model to the launching velocity. The velocity was measured by an electronic timing device. The model was retrieved by a large net hung from the wall opposite the catapult. The tests were recorded by motion pictures taken in line with the flight path from behind the apparatus, and from the side of the building at approximately right angles to the flight path.

#### TEST CONDITIONS AND PRECISION

The model was ballasted to obtain dynamic similarity to the airplane at sea level ( $\rho = 0.002378$  slug/cu ft), because limitations of the catapult apparatus made it necessary to use the lightest loading

possible. A loading was arbitrarily selected which was considered representative of mass distribution possible on the airplane. The mass characteristics of airplane and model are given in table II.

As previously indicated, the model was launched at the angle of attack and airspeed corresponding to the stall, with the control surfaces fixed at various deflections. Various modifications were made to the tail of the model to increase the fin area, typical modifications being shown in figure 3. Dimensional characteristics and locations of the canard surfaces tested are shown in figure 4.

The accuracy of measurements of the weight and mass distribution of the model is believed to be within the following limits:

Weight, percent . . . . .	$\pm 1$
Center-of-gravity location, percent $\bar{c}$ . . . . .	$\pm 1$
Moments of inertia, percent . . . . .	$\pm 5$

Controls were set with an accuracy of  $\pm 1^\circ$ .

The control deflections used for the investigation were:

Normal:

Rudder, deg . . . . .	6 right, 6 left
Horizontal-tail incidence, deg . . . . .	10 up, 30 up
Ailerons, deg . . . . .	15 up, 15 down

Increased:

Rudder, deg . . . . .	25 right, 25 left
Ailerons, deg . . . . .	25 right, 25 left

## RESULTS AND DISCUSSION

The results of the investigation were observed visually and recorded by motion-picture camera but are considered only qualitative in nature. The discussion presented herein summarizes the trends observed for various model configurations tested during a large number of flights. The angle of attack at launching was  $20^\circ$ . The results obtained were generally symmetrical to the right and left for corresponding control settings.

### Basic Model

With the rudder and ailerons set at neutral, the model was launched with horizontal-tail deflections in  $5^\circ$  increments from  $10^\circ$  to  $30^\circ$  (trailing edge up). Force-test data indicate that the horizontal-tail

setting for trim at the angle of attack tested would be approximately  $12.5^\circ$  up. When the horizontal tail was only  $10^\circ$  up, the model went into a glide with slight sideslip. When, however, the horizontal tail was  $15^\circ$  up or more, the model pitched up and then usually diverged in yaw. Although space limitations often prevented observation of more than about three-fourths of a turn in heading change, experience indicates that these motions can be considered the start of a developed spin.

With the rudder or the rudder and ailerons deflected, further tests were made at horizontal-tail settings of  $15^\circ$  (one-half up) and  $30^\circ$  (full up), the horizontal-tail range that gave pitch-up. With the horizontal tail set half up, tests were made with normal rudder settings ( $\pm 6^\circ$ ) and with aileron settings of two-thirds ( $\pm 10^\circ$ ) and full ( $\pm 15^\circ$ ) deflection. The results indicated that when spins were obtained, the model always spun in a sense opposite to the aileron deflection (i.e., a spin to the left when the aileron setting simulated stick laterally to the right). Rudder setting had some effect, however, as evidenced by the fact that left spins were obtained with lateral stick deflections of two-thirds or full right when rudder was full left, or with two-thirds of full right lateral stick deflection when the rudder was full right; but full right lateral stick deflection in conjunction with full right rudder led to a roll to the right. Brief tests made with ailerons deflected  $\pm 25^\circ$  opposite to full normal rudder (controls crossed) led to an aileron roll, with the ailerons rather than a spin in a sense opposite to the aileron deflection.

With the horizontal tail set full up and with normal full rudder setting ( $\pm 6^\circ$ ), tests made with ailerons neutral and two-thirds right or left led to a pitch-up followed by a divergence or sideslip, space limitations preventing observation for more than a moderate heading change. Thus, within the limitations of experimental results, horizontal tail full up seemed at least to slow up the spin-entry process. This result may be associated with the fact that, as indicated by force tests at the high angles of attack obtained with this horizontal-tail setting, the yawing moment due to sideslip was less unstable than at lower angles of attack and thus did not assist the ailerons in bringing about a spin. Brief tests made with a large rudder deflection ( $25^\circ$ ) indicated that even though ailerons were neutral, a developed spin was quickly obtained and about two turns could be observed even with the limited space available. Also, tests made with ailerons deflected  $\pm 20^\circ$  and the horizontal tail full up indicated that regardless of rudder setting - neutral or full right or left ( $6^\circ$ ) - the inertia coupling resulting from the rolling and pitching velocities led to extreme attitude angles which could be observed only briefly before the model entered the retrieving net.

It will be noted from the foregoing discussion that when spins were obtained with the ailerons deflected, the resulting spin rotation was always in the direction opposite to the aileron setting, regardless of

the rudder setting. This indicates that the ailerons are of primary importance in inducing spins and determining the direction of spin rotation. It appears therefore, that the pilot should avoid the use of ailerons in low-speed flight as far as possible. The results also indicate that the rudder has some effect in the incipient phase in that spins were more readily obtained when the rudder was deflected with the spin (controls crossed) than when the rudder was against the spin (controls together). The effect of aileron setting on developed spins and recoveries of current airplane types is discussed more fully in references 3 and 4.

#### Effect of Modifications

In an attempt to alleviate the yawing divergence of the model, additions to the vertical-fin area and installation of flap-type canard surfaces near the nose were investigated. These tests were made with rudder and ailerons neutral, and with horizontal-tail settings arbitrarily selected from the range for which directional divergence was observed on the basic model ( $-25^\circ$  for the tests with increased fin area and  $-20^\circ$  for the canard tests).

Increased fin area.— Typical modifications illustrating the range of fin-area increases investigated on the model are shown in figure 3. Only the configuration which resulted in the greatest increase in area (that shown as modification 4) was of any benefit in reducing the magnitude of the divergence. When the model was launched in this configuration the directional divergence did not appear, and subsequent to pitch-up the model showed only a slight lateral roll or oscillation.

Canard surfaces.— Figure 4 illustrates the plan form of the canard surfaces tested and the various locations at which they were installed on the model. The fuselage station at which the canards were positioned corresponds to the location of electrical access doors on the airplane. The most effective position was found to be 0.18 inch below the reference line on the model. With the canards installed at this position, little or no yawing tendency was observed during the portion of the flight following the pitch up and until the model entered the safety net. The influence of canard surfaces on incipient and developed spins is discussed more fully in references 4 and 5.

#### CONCLUDING REMARKS

Based on the results of an investigation of a dynamic model on a catapult at the Langley Laboratory, the following statements regarding the incipient spin characteristics of the Chance Vought XF8U-1 airplane are made:

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TABLE I.- DIMENSIONAL CHARACTERISTICS OF  
THE CHANCE VUGHT XF8U-1 AIRPLANE

Overall length, ft . . . . .	54.03
Wing:	
Span, ft . . . . .	35.67
Area (including fixed chord extension), ft . . . . .	385.33
Root chord, in. . . . .	202.00
Tip chord (including chord extension), in. . . . .	55.93
Mean aerodynamic chord, in. . . . .	141.40
Distance from leading edge of root chord rearward to leading edge of $\bar{c}$ , in. . . . .	92.68
Sweepback of quarter-chord line, deg . . . . .	42
Aspect ratio (area includes chord extension) . . . . .	3.30
Taper ratio (including chord extension) . . . . .	0.28
Dihedral, deg . . . . .	-5
Incidence, deg . . . . .	-1
Airfoil section:	
Root . . . . .	NACA 65A006
Tip . . . . .	NACA 65A005
Ailerons:	
Total area, sq ft . . . . .	41.98
Span of one aileron, percent of $b/2$ . . . . .	40.38
Horizontal tail:	
Span, ft . . . . .	19.25
Area, sq ft . . . . .	108.99
Sweepback at quarter-chord line, deg . . . . .	45
Root chord, in. . . . .	114.80
Tip chord, in. . . . .	17.20
Aspect ratio . . . . .	3.40
Dihedral, deg . . . . .	5.42
Airfoil section:	
Root . . . . .	Modified NACA 65A006
Tip . . . . .	Modified NACA 65A004
Vertical tail:	
Height, ft . . . . .	12.08
Total area, sq ft . . . . .	82.36
Rudder area, sq ft . . . . .	13.48
Sweepback at quarter-chord line, deg . . . . .	45
Root chord (at fuselage center line), in. . . . .	157.50
Tip chord, in. . . . .	41.00
Aspect ratio . . . . .	1.77
Airfoil section:	
Root . . . . .	Modified NACA 65A006
Tip . . . . .	Modified NACA 65A004

TABLE II.- MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR THE LOADINGS OF THE CHANCE VOUGHT  
XF8U-1 AIRPLANE AND FOR LOADING TESTED ON THE 1/25-SCALE MODEL

[Values given are full scale, and moments of inertia are given about the center of gravity]

Condition	Weight, lb	Center of gravity		Relative density, $\mu$	Moments of inertia, slug-ft <sup>2</sup>			Mass parameters		
		x/ $\bar{c}$	z/ $\bar{c}$		Sea level	$I_X$	$I_Y$	$I_Z$	$\frac{I_X - I_Y}{mb^2}$	$\frac{I_Y - I_Z}{mb^2}$
Airplane values										
Combat - fighter with guns and normal fuel	20,840	0.241	-0.009	19.80	10,950	82,318	89,035	$-867 \times 10^{-4}$	$-82 \times 10^{-4}$	$949 \times 10^{-4}$
Combat - 300-nautical-mile fighter with guns	20,840	0.274	-0.011	19.81	10,548	79,662	86,000	$-840 \times 10^{-4}$	$-77 \times 10^{-4}$	$917 \times 10^{-4}$
Combat - 400-nautical-mile fighter with guns	21,287	0.271	-0.013	20.23	10,814	79,834	86,358	$-821 \times 10^{-4}$	$-78 \times 10^{-4}$	$899 \times 10^{-4}$
Combat - 400-nautical-mile fighter with guns and rockets	22,034	0.249	-0.004	20.94	11,070	81,530	87,840	$-810 \times 10^{-4}$	$-72 \times 10^{-4}$	$882 \times 10^{-4}$
Spin demonstration airplane	20,250	0.310	-0.021	19.25	9,380	79,570	84,230	$-877 \times 10^{-4}$	$-58 \times 10^{-4}$	$935 \times 10^{-4}$
Model values										
Test loading	17,241	0.336	-0.036	16.37	17,556	90,511	98,479	$-1,072 \times 10^{-4}$	$-117 \times 10^{-4}$	$1,189 \times 10^{-4}$

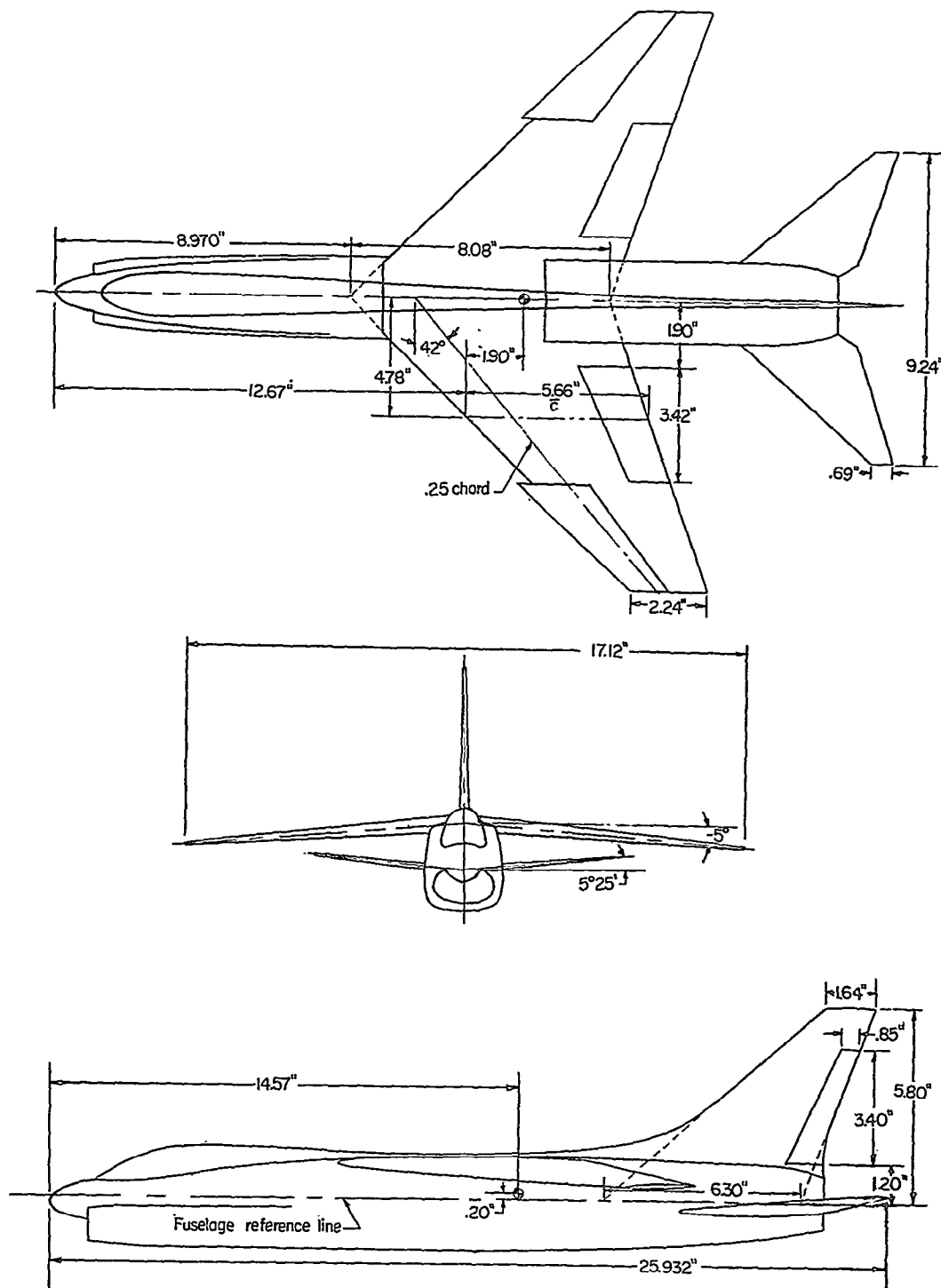


Figure 1.- Three-view drawing of a 1/25-scale model of the Chance Vought XF8U-1 airplane. Center-of-gravity position shown is for the test loading.

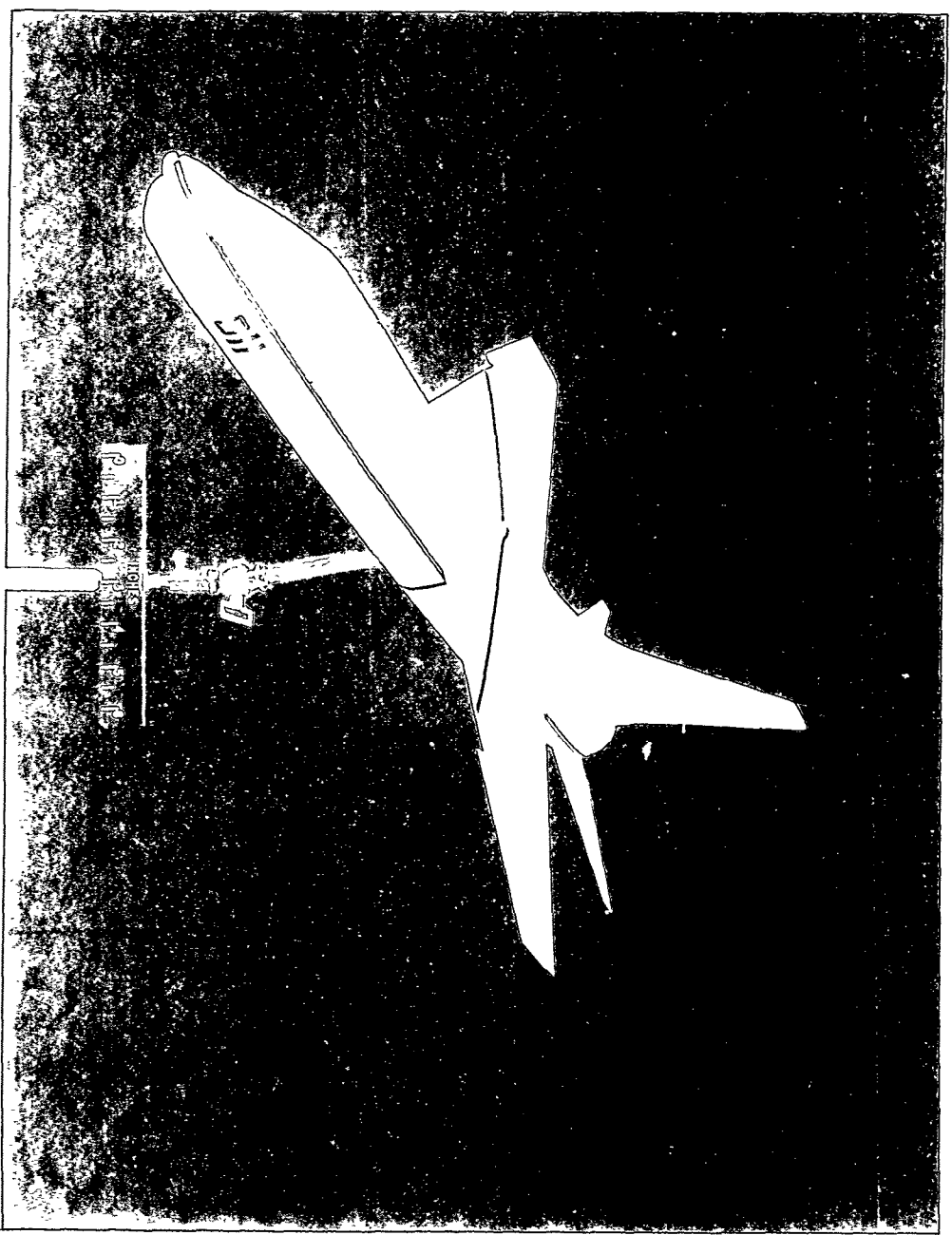


Figure 2.- Photograph of the 1/25-scale model of the Chance Vought  
XF8U-1 airplane.

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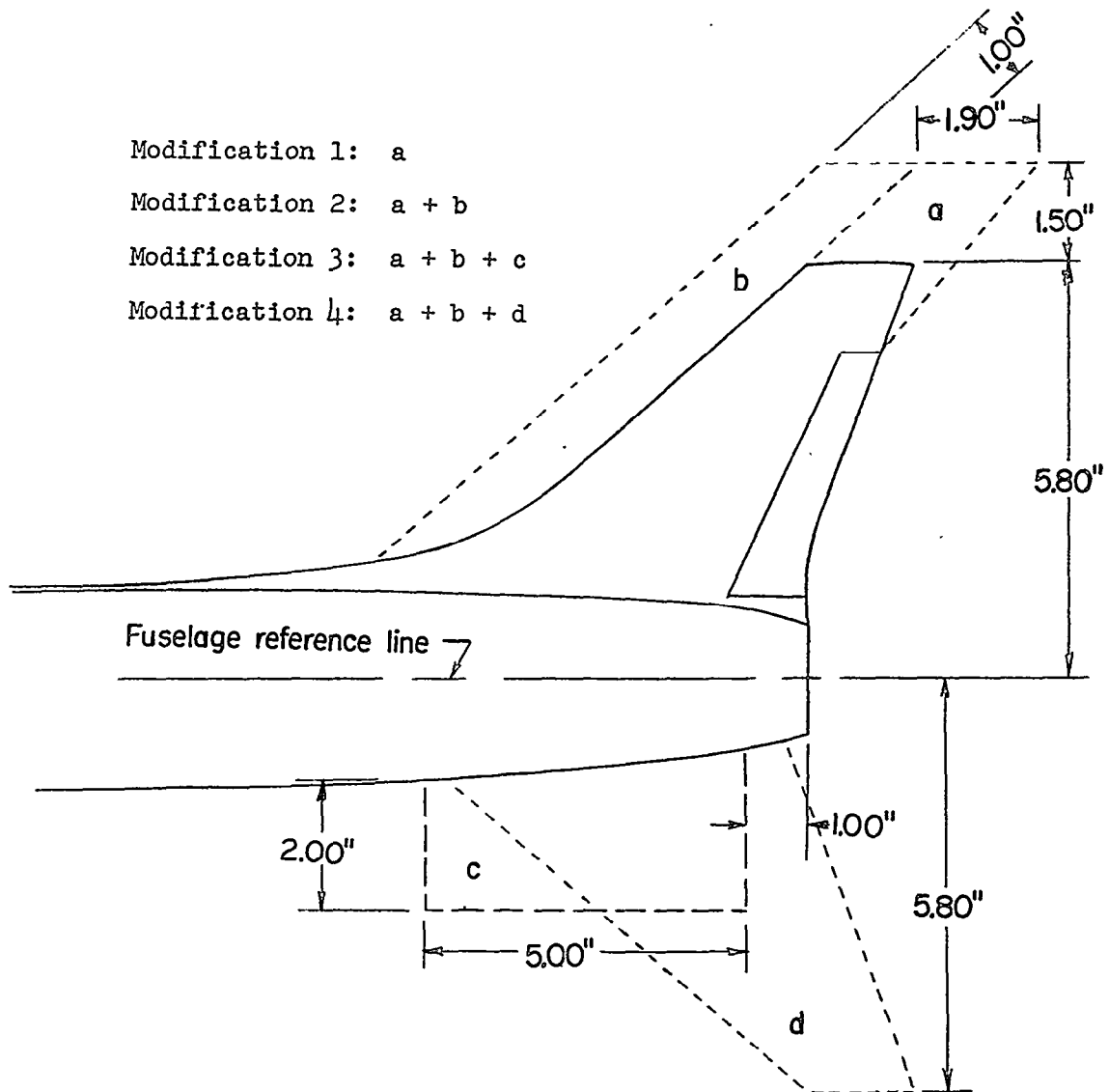


Figure 3.- Vertical-fin modifications tested on the model.

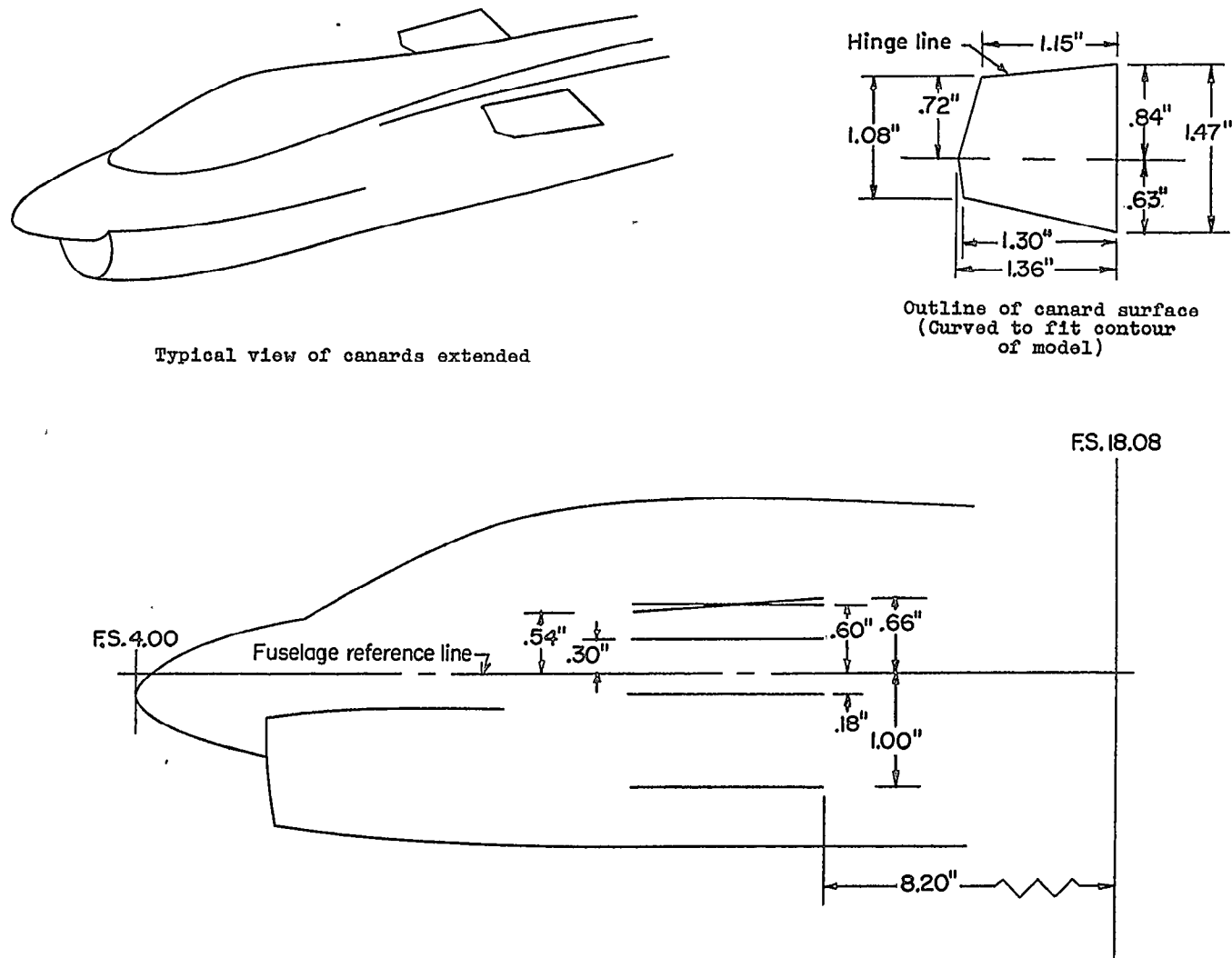


Figure 4.- Dimensional characteristics and location of canard surfaces used in tests.

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ABSTRACT

Incipient spin characteristics have been investigated on a 1/25-scale dynamic model of the Chance Vought XF8U-1 airplane. The model was launched into free flight by a catapult apparatus. The resulting motions indicated that entry into spins was readily obtained and that ailerons were very effective in initiating spin entry, the resulting rotation always being in the opposite direction to the lateral stick deflection.

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(3/20/58)

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